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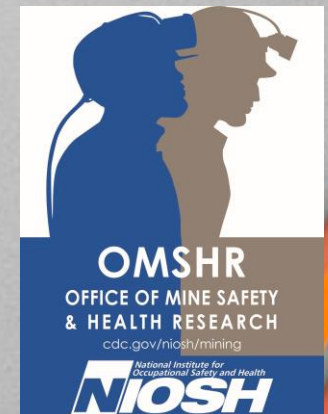
# **Cryogenic Air Breathing Apparatus and Liquid Air Fill Station for Outby Mine Escape**

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This effort is completed as part of CDC Inter-Agency Agreement (IAA/SAA)  
CDC Agreement No: 12FED1213259, NASA SAA No: KCA-4357

**Theory of operation**

**Design schematic and fabrication**

**Machine Tests**

**Human Tests**

**Conclusion**

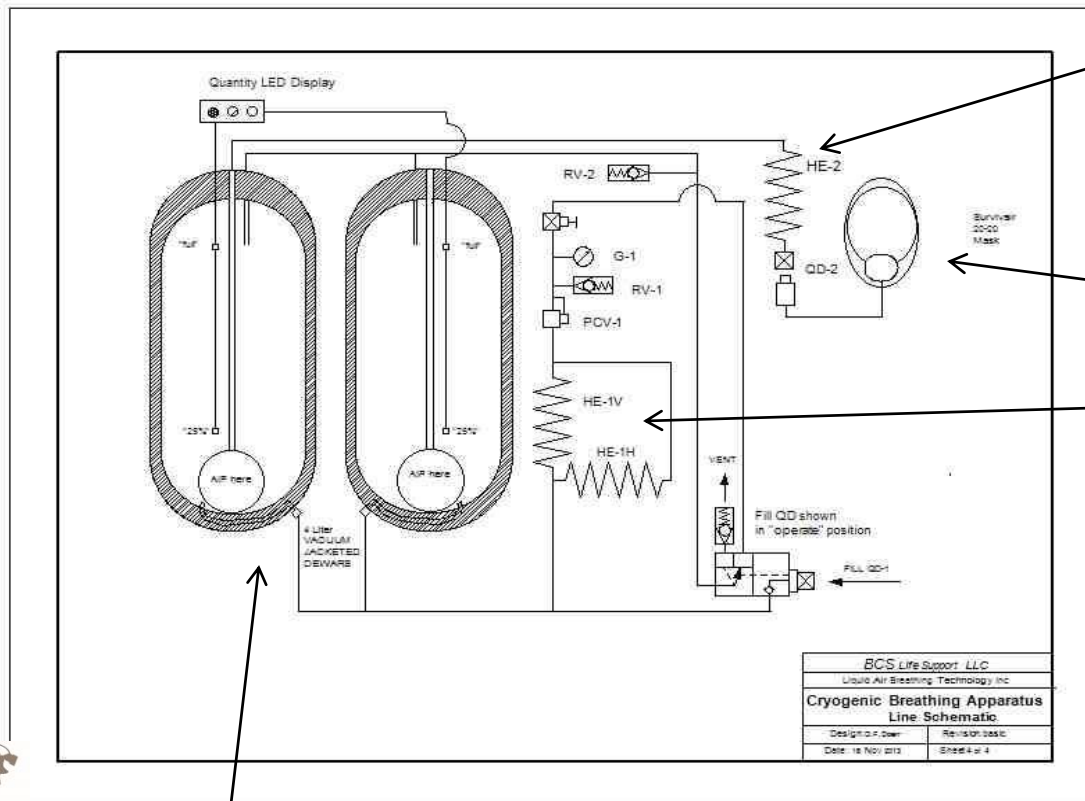
### The Cryogenic Breathing Apparatus

- Uses cryogenic (liquid air)
  - 53 lb/ft<sup>3</sup>(1.14 gm/cm<sup>3</sup>), - 318°F(77°K), store at very low pressure
  - Contains 8 liters
- Liquid air stored in 2 Dewars (metal thermos bottles)
- Liquid expands 728:1 to produce gaseous air in a heat exchanger
- Gas at 75 psi and approximately 55°F fed to mask
- Mask is conventional positive pressure, demand



# How does CryoBA work?

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**Heat exchanger  
for supply loop**

**Pressure demand  
SCBA mask**

**Buildup loop  
(pressurizes system)**

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## Two Prototypes designed

- 1 – wide spaced Dewars – minimum thickness
- 2 – close spaced Dewars – narrow pack

Add pics if CryoBA2 here

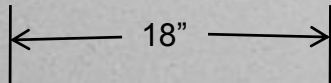


**CryoBA prototype 1**

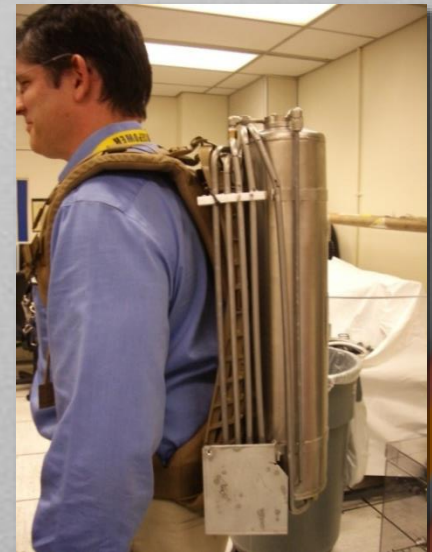


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- Operates in 90° off-vertical attitudes
- Positive pressure demand SCBA
- Provides cool source of air for 2 hours
- Carries 14 lb liquid air, total pack weight = 42 lb (19kg)
- Can meet 29 CFR part 84 requirements
- Low profile (approx 7" (17.8cm) deep)



User operated fill QD

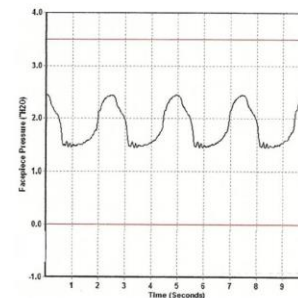
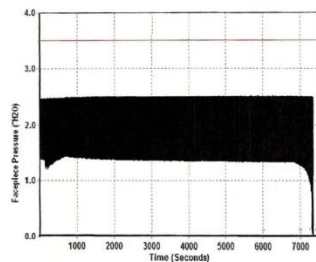


### Perform machine testing on Posichek3

- Testing at NIOSH 40 l/min
- No body heat to aid heat exchanger
- No active air circulation (person moving)
- Off-vertical attitudes tested



Mask pressure waveforms  
10 sec (left) - 2 hours (right)





- **Protocols approved by NASA and NIOSH IRB's**
- **Protocols per 42 CFR 84 subpart H**
- **Subjects instrumented for ECG**
- **CryoBA instrumented for O<sub>2</sub>, CO<sub>2</sub>, pressure, temp.**
- **Exercise per Tables 1, 3 and 4 – each for 2 hours**
  - **Treadmill walking, crawling**
  - **Wall pulley**
  - **Overcast carrying weight**
  - **Resting prone, supine, left side, right side**
- **Off-vertical tests – 30 minutes each**
  - **Full and ¼ full**
  - **Prone, supine, left side, right side**



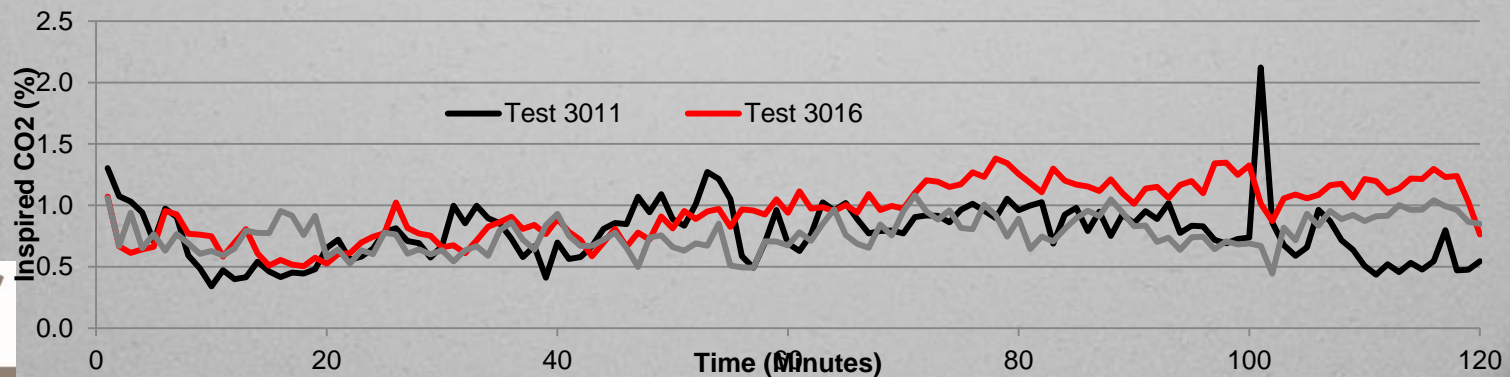
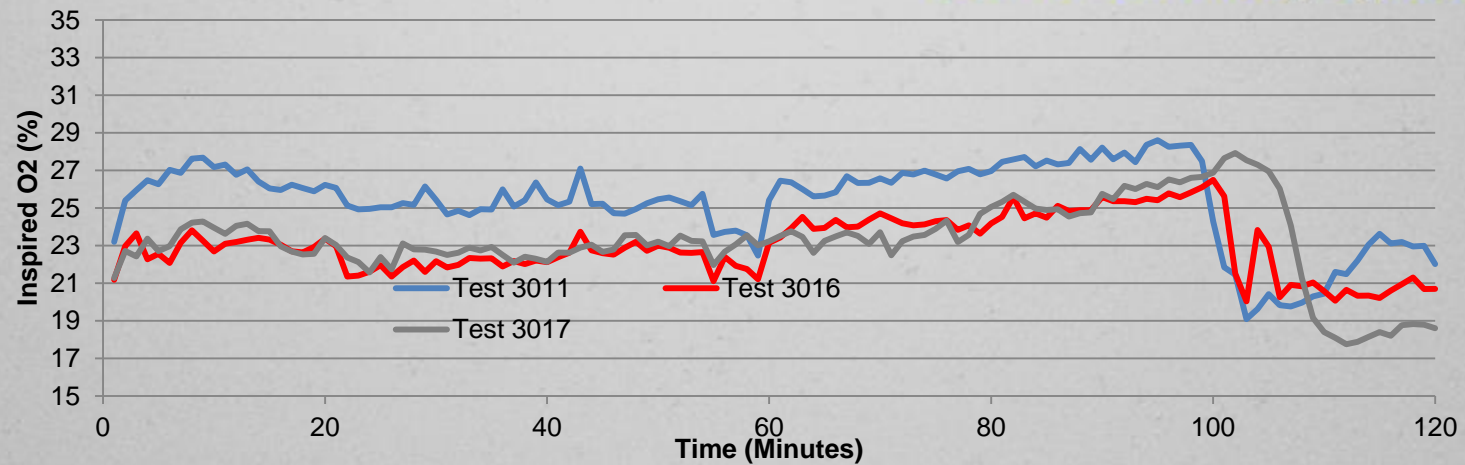
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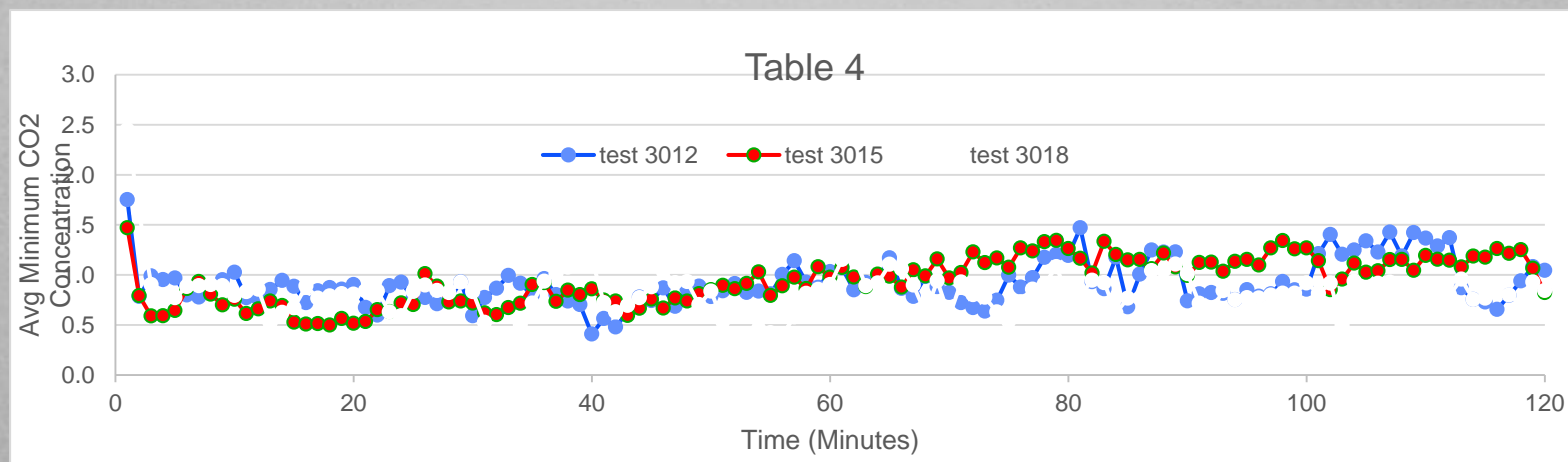
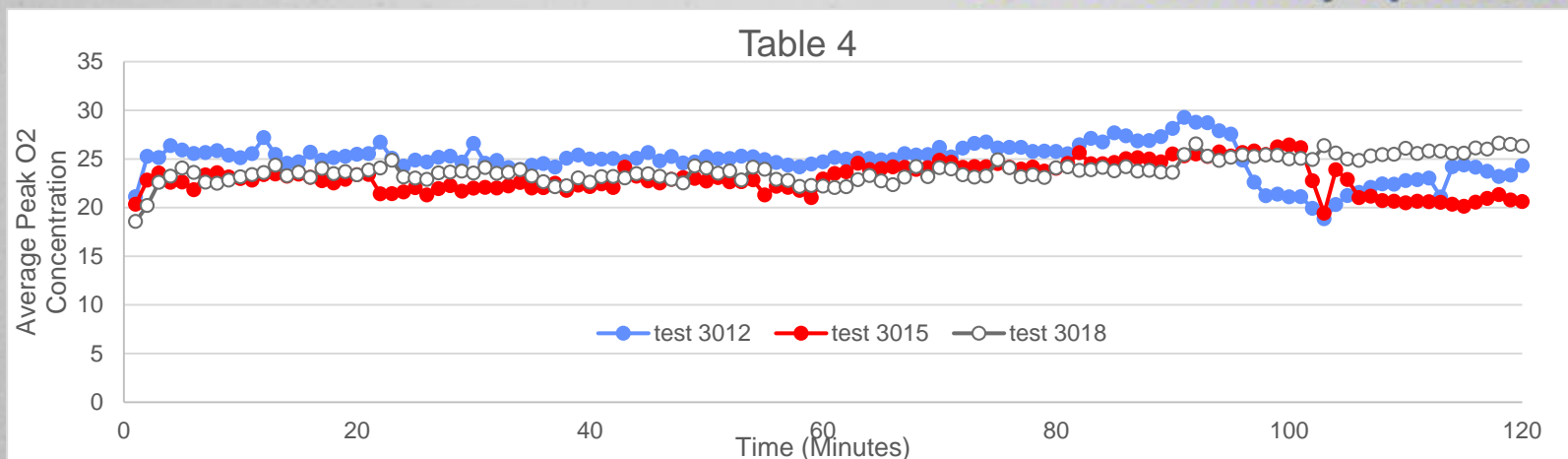
# Human Protocols – Results

## Table 3

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- Additional data:
  - Mask Pressure
    - Always positive
    - Varied between +1 IWG to 3.5 IWG
  - Mask Temperature
    - Inhaled/exhaled temperature monitored
    - Ranged between 75 – 85°F

## Summary

- Oxygen measure inside oral nasal mask – normal
- CO<sub>2</sub> measured inside oral nasal mask – normal
- Mask pressure - +1 IWG to +3.5 IWG
- Mask temperatures reflect exhaled temps cooled by incoming air - 75°F to 85°F
- Duration – 2 hours

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- Use CryoASFS to fill cryogenic breathing apparatus
- User can fill
- User can breathe on mask while filling
- Fill time – approx 4 minutes
- Prototype 1 ASFS can fill 4 units simultaneously
- ASFS has capability to perform multiple serial fills (~40)
- Locate every 1:30 in egress path

CryoBA + 3 other  
packs being filled





## Conclusion

- This 2 hour version of the NASA Liquid Air Pack can meet 29 CFR 84 subpart H requirements
- Simple for miner to initial fill (while breathing)
- Simple for miner to refill during egress every 1:30
- This pack should meet needs of miners escaping disaster
- Could use within a Level A encapsulated suit to provide heat stress relief for hazardous material operations



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